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ltpetre: Its Origin and Extraction in India

BY

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of saltpetre. It is this surface layer only which the *nuniahs*[1] collect for extraction, and it is in the calcareous portions of the Gangetic alluvium that these soil conditions obtain and in Bihar especially that they are combined with those climatic ones above described as favourable.

The method of the *nuniah* in obtaining saltpetre has been described in several publications, notably by D. Hooper, in *Agricultural Ledger*, No. 3, 1905, p. 26, and by Leather and Mukerji in *Bulletin No. 24 of the Agricultural Research Institute, Pusa*, 1911; in the latter publication more particular attention was given to the refining of the crude material and no consideration of the improvement of the industry would be complete without taking into account the important modifications and improvements in this process devised and successfully carried out by these authors.

The present writer has been mainly concerned with the manner in which saltpetre originates in the soil and is recovered therefrom by the *nuniah*, and for the better understanding of the following discussion of the possibilities of the industry, it will be well to give here a short description of the methods in use by *nuniahs* in Bihar, these methods showing but little variation from one district to another all over India, the only serious one being the use in some parts of the country, especially in the Punjab, of the direct heat of the sun for concentrating the nitrate liquors, in place of fuel.

The *nuniah* detects the occurrence of saltpetre in the soil by sight, touch and taste, slight difference in these qualities which his experience allows him to recognize enabling him to distinguish *nuni-matti, i.e.*, earth containing saltpetre, from other saline deposits such as *khari* or sodium sulphate. Saltpetre occurs concentrated only in the surface, and the *nuniah* removes this by scraping it off to a depth of about one quarter of an inch with a *khurpi* or small flat trowel; the earth thus collected is known as *chhilua* and before extraction is mixed with an equal quantity of residual earth from previous extractions known as *bhinjua*. This *bhinjua* goes through a special course of preparation before use, the method and objects of which will be described later.

Extraction is carried out in a circular filter bed or *kuthie* some 4′ 6″ in diameter and 1′ 6″ deep consisting of a mud wall and floor plastered with clay and having a platform of bamboos and straw about 4 inches above the ground, upon which the earth to be extracted is placed and

[1] *Nuniah* is the name given in Bihar to the workers in saltpetre, who carry on by hereditary tradition the various operations connected with the recovery of this substance from the soil.

PLATE II

TREADING IN THE EARTH INTO THE KUTHIA FOR EXTRACTION.

carefully compacted by treading, to such a consistency as to allow of even percolation of water, which is poured upon it and filters through, carrying off in solution the saltpetre and other soluble matters contained in the soil. The percolating water is collected in an earthen vessel but only the first lot collected (*murhan*) is actually boiled down, as it removes such a large percentage of the total nitrate present in the earth that the subsequently collected liquor (*dweji*) is too weak a solution to pay for extraction, but is used as will be subsequently shown in the preparation of *bhinjua*.

The *murhan* or first extract is then boiled down in an open pan over a fire, the fuel used being mainly dead leaves either of bamboos or of trees, the ashes of which are subsequently employed for mixing with the extracted earth in the preparation of *bhinjua*, but are not mixed with the *chhilua* before extraction as erroneously stated by Leather and Mukerji, nor is wood ash generally employed, but usually leaf ash. The boiling of the *murhan* is continued until a point in concentration is arrived at at which drops of the liquid taken out in a small vessel and allowed to drip from it congeal perceptibly on cooling; another method is to place a drop upon the thumb nail and observe the formation of crystals. When judged ready the fire is allowed to die out and after cooling the liquid is carefully ladled out into earthenware pots where it cools down further, depositing crystals of saltpetre contaminated with adherent sodium chloride.

In the ordinary process of the *nuniah*, boiling down is stopped before any considerable separation of salt takes place; this occurs however in the subsequent cooling down and crystallizing out of the saltpetre, which thus becomes contaminated with salt.

The refiner who, as will be shown later, carries on saltpetre extraction from soil in his factory by the same process as the *nuniah*, being in a position to separate salt under license, carries his boiling to a further point than the *nuniah*, and so separates some salt at this stage of the process.

The liquid concentrated by boiling, known as *mal*, is removed from the boiling pan and allowed to cool in earthenware vessels; it contains in solution besides saltpetre, other salts such as those of sodium, calcium and magnesium and when cooled down deposits crystals of saltpetre contaminated with varying amounts of these impurities, of which sodium chloride generally forms the largest proportion, sometimes amounting to more than thirty per cent of the crude saltpetre. No further attempt at purification is made by the *nuniah* but rather the reverse as he adds to this impure mixture the solid residue from the boiling pan known to

him as *gad;* this consists partly of particles of soil and partly of organic matter thrown out of solution by the boiling, but originally dissolved out of the earth in the *kuthia;* this organic matter is generally brown in colour, as was the watery soil extract, and when mixed by the *nuniah* with the comparatively white crystals of saltpetre, imparts to them the dirty appearance which, as is mentioned later in the paper, is supposed to convince the officials of the Salt Department that the *nuniah* has made no attempt to separate salt from his *shora*. Its other peculiar function which renders its presence acceptable to the refiner is described later.

Having now separated the impure saltpetre or *shora* and added thereto the *gad*, the *nuniah* is left with :—

(1) The later fractions of the percolate from the *kuthia* known as *dweji* which were described as being too weak to be worth boiling down.

(2) The mother liquor (*kahi*) from which some of the saltpetre was separated, containing besides unrecovered saltpetre large quantities of saline matters in solution especially sodium chloride.

(3) The extracted earth in the *kuthia*. (*Sitta*.)

All these contain certain residual amounts of saltpetre and the object of the *nuniah* is to recover some of this residue, which he does by means of a secondary series of operations carried out concurrently with the main one above described.

It is of interest to note here that although the *kahi* or mother liquor after the usual percentage of saltpetre has been separated from it by the crystallizing process still contains so much of this salt, in some cases more than equal in amount to that removed as *shora*, the *nuniah* makes no attempt to recover it by a further separation at this stage. This may be explained partly by the fact that this would involve separation of salt, forbidden by the Salt Department, and partly because the *nuniah's* experience tells him that it may result in loss of nitrate due to decomposition during the further concentration by boiling. Such loss is avoided by the method of the *nuniah*, who returns the *kahi* with its content of nitrate to the general store by adding it to his *bhinjua* and thus bringing it into circulation again for further extraction in the *kuthia* during the following season. That such loss as is referred to does actually occur on further concentration has been shown by experiment, but it is difficult to understand how the *nuniah* has

arrived at any knowledge of it, and it is probable that his usual practice has been regulated more by consideration of the Salt Department's requirements than by his own in this instance.

The secondary series referred to consists in the treatment of the residues from the first extraction in such a way as to recover from them as much as possible of the nitrogen which has escaped recovery in the original process. This treatment consists in adding to the extracted earth the second percolate (*dweji*) above referred to, the mother liquor from the crystallizing vessel (*kahi*) and some ashes from the fireplace. Thus the mixture will contain all the nitrogen which escaped extraction including an important fraction in the form of organic nitrogen which was originally present in the *chhilua*. The earth with these additions is carefully worked up so as to distribute the moisture evenly throughout it, and the *nuniahs* state that their object in adding ashes is to obtain this result and prevent puddling of the soil; it is then spread out in the sun and turned over every three or four days to ensure even drying out, the operation being considered complete in about three weeks time. The treated earth is now known as *bhinjua* and forms an essential part of the stock-in-trade of the *nuniahs*' business, as it is universally stated by them that no successful extraction of *chhilua* can be carried out without the admixture of a considerable proportion of *bhinjua*. Actual experiment and analysis of numerous samples in this laboratory has shown that rapid nitrification of the organic matter present in the *bhinjua* takes place during its preparation and as there is a considerable quantity of organic nitrogen in the *chhilua* brought in for extraction, and remaining in the *sitta*, its nitrification results in producing *bhinjua* containing in some cases as much saltpetre as does the *chhilua* with which it is mixed for extraction in the *kuthia*. Thus the preparation and use of *bhinjua* brings into circulation again in the factory not only nitrate which escaped recovery in the first process but also nitrogen which had not yet been nitrified in the village earth; both *nuniah* and refiner agree in saying that saltpetre "grows" in their residual earth, and it should be remarked that the latter is not used for the preparation of *bhinjua* during the same year as its extraction and conversion from *chhilua* into *sitta*, but is stored, preferably under shelter, until the the following season, thus allowing time for a considerable conversion of organic nitrogen into nitrate before being made into *bhinjua*. The *nuniahs* are practically united in their opinion that the best *bhinjua* is made from one year old *sitta*; at this period the content of nitrate is highest, whereas further storage for one or two years diminishes the amount. This opinion agrees not only with analytical determinations made of samples of varying age, but with the fact observed in this

laboratory that nitrate reduction by soil bacteria frequently takes place in the soils of this district after storing.

At the end of the saltpetre season, which occurs at the commencement of the rains, the *nuniah* possesses a supply of unused *bhinjua* which he stores carefully against the beginning of the next year's operations.

The earth of which the *kuthia* walls and floor were made, becomes impregnated with saltpetre which it absorbs from the percolating water. After two months use the *kuthia* is broken up and used for the preparation of *bhinjua*, thus recovering some of the lost nitrate.

Occasionally the *nuniah* incorporates large quantities of old *sitta* with the new earth walls of his house, the inside surfaces of which are plastered with a mixture of chopped straw, clay and cowdung, the outside being left untreated. On the outside of the walls the saltpetre formed by nitrification of the cowdung and of the organic matter in the *sitta* appears as an incrustation which is scraped off to be used as *chhilua*, and in process of time the whole house is pulled down and the earth made use of in the same way. This particular method of using *sitta* is of great interest as it affords a good example of selection by empiricism so common in Indian industries, where the native with the advantage of generations of predecessors engaged in the same occupation, under conditions where the narrowest margin of profit existed and still exists, has evolved, as in this instance, a very efficient method of inducing a high percentage of nitrification of the organic matter present in his soil, and of recovering the nitrate formed. Nitrification, in common with other bacterial processes, is hindered by accumulation of the products of bacterial action, in this case nitrate. In addition the nitrate formed is liable to be destroyed by other soil bacteria, so that the most favourable conditions for formation and accumulation of nitrate would involve the removal of the latter *pari passu* with its formation, to a region sufficiently remote from that of production to insure not only non-interference with the activity of the nitrifying organisms, but immunity from attack by other soil bacteria. Such conditions are found in the walls of the *nuniah's* house where nitrification of the cowdung and straw as well as of other organic matter in the earth of which they are built, proceeds on the inner side with all the more rapidity as the moisture moving through the wall towards the outer sun-dried surface carries with it the nitrate formed, and deposits it on this surface in concentrated form within easy reach of the *nuniah*. At the same time there is free access of the air required to the inner nitrifying surface, whereas in the case of soil under ordinary conditions, although surface evaporation and concentration of nitrate are going on,

aeration of the lower nitrifying stratum is frequently necessarily deficient; on the other hand, in the loose well-aerated soil used by the *nuniah* for the preparation of *bhinjua* this movement of nitrate does not occur, thus not only limiting nitrification but making it necessary to deal with the whole mass in order to recover the saltpetre formed.

(1) **Nitrifiable organic matter.** As conditions are at present saltpetre is obtained principally, if not entirely, in the immediate neighbourhood of human habitations either existing, or of abandoned village sites, where constant accumulation of organic refuse has gone on. This refuse includes excrement and urine both of man and domestic animals, the high percentage of sodium chloride occurring as an impurity in saltpetre indicating the human origin of much of it. Where exceptions to this general rule occur it may be that accumulations of vegetable growth have previously existed due either to natural causes or human interference, but such exceptions are rare, practically the whole supply of *chhilua*, *i.e.*, the nitrate earth scraped off and collected by the *nuniah*, being derived from village sites either old or new. No special bacterial action is needed to explain the accumulations which occur, nor do the nitrifying bacteria found associated with these nitre earths possess any abnormal nitrifying powers, in fact in the earths themselves the concentration of nitrate is frequently above the maximum of nitrification possible in soil.

Experiments with Bihar soils show that the capillary rise of water therein, produced by rapid evaporation during the dry season of the year, is sufficient to raise to the surface the major portion of the nitrate distributed through them, producing the high concentrations both of nitre and other salts characteristic of *nuni-matti*. Thus whilst the highly favourable conditions for nitrification of high temperature and adequate air and moisture exist in these soils, there is no necessity for the occurrence of any special nitrifying organism to explain the high concentrations found in the surface layers, nor has any such been found here.

The occurrence therefore of saltpetre deposits indicates the concentration in comparatively small village sites of nitrogen derived from plants grown over the whole area supplying food to the human beings and their cattle in that village. So far as the potash constituent is concerned this may or may not be derived from the same area, as a large proportion of it is derived from the ashes of the fuel collected possibly from a different one. In any case it will be seen that the production of saltpetre represents the recovery from the soil of nitrogen which has been collected from a large area and concentrated in a small one, and which would in all probability be lost as an asset of the community if not recovered in this way. It is of interest to note that although

so far as the saltpetre industry is concerned this concentration in limited areas, coupled with a further concentration in the surface layer, is necessary for economic recovery of the nitrogen as saltpetre, yet the same soil and climatic conditions which produce this result in village earths containing large quantities of organic matter, produce a similar one in the field soils containing normal amounts. Thus it has been found as a result of observations made in connection with this enquiry, that during the cold weather in Bihar, when the *rabi* crops are in the ground, the nitrate formed in the soil is brought to the surface by the capillary rise and evaporation of soil water, so that in an untilled soil about 90% of the whole of the nitrate present in the first 18 inches of soil is concentrated in the first quarter inch. This emphasizes the necessity for cultivation during this period of the year not only to minimize loss of water by evaporation, but to prevent the concentration of the available nitrogenous plant food in such a superficial layer and the consequent formation of a shallow root system so characteristic of plants in a badly cultivated soil and especially noticeable in the case of cold weather cereals of normally deep-rooting habit such as wheat.

Although this process of concentration goes on in the ordinary field soil the amount of nitrifiable organic matter contained in the latter and brought to the surface as nitrate is not sufficient to pay for collection and extraction; hence the *nuniah's* operations are confined to those situations where larger amounts are to be found for the reasons mentioned above. This raises the question whether the output of saltpetre from a district such as Bihar is not already limited by its restriction to village sites or whether this output could be increased either by fuller use of the saltpetre earth available in such localities, or by exploitation of some other source.

Village Earth. Enquiry in the districts of Darbhanga, Muzaffarpur and Champaran shows that the amount of saltpetre produced therein does not by any means represent the full capacity of these earths, but rather the number of *nuniahs* engaged in this industry during the season, nor does this number represent that of the men of this class resident in the district but only that proportion of them who have decided to work at their characteristic occupation rather than undertake the alternative ones of pure agriculture or perhaps earth work on railways, roads, canals or the like. It is in fact exceptional to find all the members of a family of *nuniahs* engaged in saltpetre extraction even during the seven or eight months of the season appropriate for this work. Nearly all of them cultivate land, and in unfavourable seasons when the price of *shora*, *i.e.*, crude saltpetre, is low, a large proportion of the family will turn to one of the other above-mentioned occupations

for which their traditions and experience peculiarly fit them. In normal seasons it appears that the *nuniah's* preference inclines towards saltpetre production, as this in the hot weather is of a more sedentary character than agriculture or earthwork, and allows not only of assistance from the female members of the family, but of considerable periods of contemplation in the necessarily protracted intervals of the work. The actual amount of *shora* turned out by a *nuniah* and his establishment depends ultimately upon the number of boiling pans he possesses, and this will be determined partly by his pecuniary resources, as he must buy these and keep them in repair, and partly by the labour which he can command, either from his own family or community, or by hire. Here again enquiry seems to show that the limiting factor is not the amount of *nuni-matti* (saltpetre earth) obtainable, but rather the labour available, this again depending upon the choice between alternative occupations largely determined ultimately by the market price of crude saltpetre. Another factor is the cost of fuel, but in the majority of cases investigated by the writer this is relatively insignificant, although of course it does actually prohibit the extraction of earths of low saltpetre content. Other factors of no inconsiderable importance militate against the decision of the *nuniah* to engage in saltpetre production; these include difficulties arising from the relationships existing between landlord and tenant and the necessity in some cases for the *nuniah* to pay both of them for the right to remove saltpetre, and the regulations of the Salt Department which forbid the *nuniah* to separate the common salt which forms such a considerable portion of the impurities associated with saltpetre, and by so doing prevent him from producing a purer article fetching a good price; this results in his deliberately adding other impurities as make-weights,[1] because the refiner who separates salt under Government supervision, and is in a position to fix the price of the crude article, gives him no encouragement to do otherwise. This is particularly the case so far as the *gad* or insoluble residue in the boiling pan is concerned; this consists partly of earth carried in suspension by the extraction water from the filter bed or *kuthi* and partly of precipitated organic matter, and is deliberately added to and mixed with the *shora* or crude saltpetre, forming in some cases as much as twenty per cent of the weight of the latter. This state of affairs is recognized and aggravated by the convention adhered to by the refiner of demanding

[1] A similar condition obtained some years since in the case of Indian wheat, when no account was taken of purity or cleanness of the grain, this resulting in the deliberate admixture, by the Indian grower, of soil as make-weight; a considerable trade was done in England by the millers who sold this finely triturated soil as a metal polish to brass finishers.

sometimes as much as 60 seers in the maund of *shora* when buying this from the *nuniah*.

Most refiners prefer to buy *shora* (crude saltpetre) containing a large percentage of impurities, that is, of those of organic origin and composition, thrown out of solution in the boiling pan, and forming as precipitated matter together with soil particles the insoluble residue referred to above as *gad* which the *nuniah* collects and adds to his separated *shora*. This organic matter after a second separation in the refinery forms the *sitta* or refuse earth which the refiner stores and from which he eventually extracts nitrate by the same process as that of the *nuniah*. This operation or second extraction is carried on in the refineries at that time of year, the end of the cold and beginning of the hot weather, when supplies of *shora* from the *nuniah* have not yet accumulated in the refinery to a sufficient extent to make it convenient to deal with them, and it thus fills a gap in the refiner's year which would otherwise be unoccupied. Nevertheless the whole arrangement appears wasteful of time and labour to an extraordinary degree; the refiner is actually buying two sets of raw materials; saltpetre containing salt, and earth containing saltpetre and organic matter, the second of which is actually added to the first by the *nuniah* after he has already separated them, this separation being again undertaken by the refiner in order to give his workmen something to do during the hot weather. The practical result is the waste of valuable fue and the inevitable loss of nitrate which, as has been clearly shown by Leather and Mukherji (*Bulletin No. 24, Agri. Res. Inst., Pusa*, 1911), takes place every time it is separated by the present methods. The mixture of impurities (*gad*) sold by the *nuniah* along with his *shora* could quite well be added by him to his refuse earth to be treated in due course in the preparation of *bhinjua*, its organic nitrogen being converted into nitrate in this process, along with that contained in the other extracted earth. The *nuniah* himself gives another reason for the addition of *gad* to his *shora;* his bugbear is the Salt Department menial whose business it is to suspect him of separating salt for private consumption and in order to carry conviction of his probity in this matter he adds *gad* to his *shora* thus providing a brown discoloration of the otherwise nearly white saltpetre and therewith a suggestion that no unnecessary refinement has been carried out. This method probably deceives no one and certainly not the Salt Department official, but it appears to be a widespread convention.

So far as the writer has been able to discover there is nothing to prevent the *nuniah* himself from producing refined saltpetre except the restrictions of the Salt Department, and his own incapacity as a

PLATE III

THE CHULHA AND BOILING PAN.

business man to deal with the finished product. No special apparatus is required, as has been demonstrated to the writer on more than one occasion, when high class refined saltpetre has been produced at his request by a *nuniah* with no other implements than those he was using for the production of the crude material. The refiner is a man of capital who can afford to buy crude *shora* in a cheap market and sell the refined article *kalmi shora* in a dear one, but he also complains of the vexatious restrictions of the Salt Department which prevent him from obtaining adequate remuneration for the salt which he separates. A suggestion has been made to the writer by a refiner that the imposition of a tax on saltpetre, with a corresponding relaxation of the restrictions on the production of salt, would meet the requirements of the case.

So far as the *nuniah* is concerned, it seems clear that he, as producer of a raw material, is not at present getting a fair share of the price. Thus at present prices the *nuniah* gets about Rs. 5 for his maund of say 100 lb. crude saltpetre containing about 50 lb. of the pure salt, whereas the refiner gets about Rs. 12 for one 80 lb. maund of his refined product containing some 72 lb. of pure saltpetre; thus the latter sells for about Rs. 8 what he buys from the *nuniah* for Rs. 5.

This difference is not at all commensurate with the cost of the refining process, but owing to lack of competition, the refiner is able to fix the price of crude saltpetre at the minimum which will ensure him a supply, *i.e.*, just high enough to make it worth while for the number of *nuniahs* necessary to supply the refinery, to carry on their trade. The *nuniah* at the beginning of the season agrees to produce *shora* at a certain price and as he is a poor man and lives, *more suo*, from hand to mouth he cannot afford to stand out for a better one, even although during the six months he is working the market price for refined saltpetre may rise considerably; nor is he apparently able to combine with other *nuniahs* in his district to fix a better price. In many districts a middleman who buys *shora* from the *nuniah* and sells it to the refiner absorbs much of the profits of the industry to its further detriment.

The above considerations tend to show that the *nuniah* class are offered but slight inducement to extend the scope of their operations, and so far as the writer has been able to discover it is this condition of affairs which has limited the output of saltpetre rather than any restriction in the material actually available.

Artificial Nitre production. At the beginning of this enquiry it was determined to investigate the possibilities of artificially increasing the supply of saltpetre earth by the use of nitre-beds such as were common in France during the Napoleonic wars, when the supply of Indian

saltpetre, upon which the manufacture of gunpowder then depended, was cut off from the French by our naval supremacy, just as that of Chili saltpetre is at present from Germany. An easily available source of organic nitrogen was selected in the form of Sunn-hemp (*Crotalaria juncea*) and this was buried in heaps of soil which were kept under various conditions of moisture and aeration during the following year; the experiment was commenced in the beginning of August 1915 and weekly samples were taken from various depths in the heaps to determine the rate of formation and vertical distribution of nitrate; after 18 weeks nitrate equivalent to more than half the organic nitrogen originally added was found, and six weeks later surface scrapings taken by a *nuniah* in the ordinary way yielded a good return of saltpetre. The high temperatures and otherwise favourable climatic and soil conditions obtaining in Bihar suggest that this method of supplementing the more ordinary sources of saltpetre might be adopted with advantage, should any expansion of the industry lead to probable depletion of the latter. the establishment of nitre-beds round a central factory which would carry on both extraction and refining being probably the most economical and efficient method of carrying out such expansion and placing the industry on a sound industrial basis.

Lime. When any large quantity of organic matter occurs in a soil a corresponding amount of calcium carbonate greatly favours its rapid nitrification. Hence the highly calcareous soils of Bihar are particularly suitable for the conversion of the accumulations of nitrogenous organic matter occurring in and around villages into their equivalent saltpetre.

Water. Water is naturally a limiting factor in the formation of saltpetre, depending as this does upon the biologic activity of soil organisms; considered in conjunction with suitable soil and climatic conditions, it may be stated briefly that in the first instance sufficient water is required (about 16% in a typical light Bihar soil) for formation of nitrate, any excess being detrimental as tending to arrest nitrification for various reasons, and secondly a sufficient supply must be available to keep a constant movement of water to the surface, where concentration of the nitrate dissolved in the soil water results as a consequence of evaporation. The soil also must be of such a texture as to allow of such capillary movement and also to promote nitrification; these two aims could only be attained in a soil of neither too close a grain such as a clay, nor of too open a character such as a coarse sand. The fine grained alluvial soils of parts of Bihar not only supply the mean required but, owing to their tendency to form a surface crust, promote rapid evaporation during dry weather.

The climate most suitable for production of saltpetre provides rainfall and sunshine periods, during the first of which nitrification is carried out in the soil, whereas during the second, the cold and hot weather, the absence of rain together with the dryness of the air and heat of the sun ensures a steady rise of water to the surface, carrying with it the soil nitrates. The *nuniah* begins work with the cessation of the rains and carries it on throughout the cold weather and the succeeding hot season. He holds that seasonal variations occur in the yield of saltpetre from the soils he works; thus his early operations are not generally very fruitful, which however may probably be attributed to the fact that the newly made walls and floors of his *kuthias* absorb a good deal of nitre for some time until they become saturated. Again towards the end of the season he complains once more of poor yields, but this may be explained by assuming that the best sites for collecting *chhilua* have all been worked over, and are now being gone over again, perhaps for the third time, whereas the soil water may have lost its connection with that of the subsoil, or the water table may have gone down below the limit of capillary rise to the surface.

It may be of interest to trace the circulation of the nitrogen both as saltpetre and as an organic constituent in the course of the operations of the *nuniah*. Numerous analyses of the various items of his stock from *chhilua* to *shora* show the relative amounts of nitrogen which are recovered as crude saltpetre, or pass into the residues of his factory, not to be thrown away, but brought again into circulation as *bhinjua*.

Circulation of nitrogen in the nuniah's factory. The nitrogen collected by the *nuniah* and brought into his factory exists in two forms (1) Nitrates, either of potassium, calcium or magnesium. (2) Organic nitrogen. It will be simpler to consider the nitrate form separately and to assume that it exists as nitrate of potash, or saltpetre: the addition of ashes to the earth in the preparation of *bhinjua* probably ensures the conversion of a considerable proportion of the other nitrates into this compound before extraction in the *kuthia* although there is reason to believe from experimental data that in many cases this conversion is incomplete. Numerous analyses of the earths, watery extracts, and crystalline products in the factory lead to the following general conclusions:—

The earth put into the *kuthia* for extraction generally consists of about equal portions of that collected outside (*chhilua*) and treated residual earth (*bhinjua*); the percolating water collected is divided into 1st and 2nd portions of which only the first (*murhan*) is boiled down, the second being poured back on to the extracted earth (*sitta*)

to make *bhinjua*. This *murhan* removes in solution about 80 per cent of the nitrate present in the *kuthia* and this solution is concentrated by heating, cooled down, and the saltpetre crystals formed taken out, mixed with the *gad* or sediment from the boiling pan, and sold as crude saltpetre or *kutcha shora*. This contains about 50 per cent of the saltpetre present in the water extract or *murhan* (*i.e.*, about 40 per cent of that originally in the *kuthia*), the other 50 per cent remaining in the mother liquor or *kahi*.

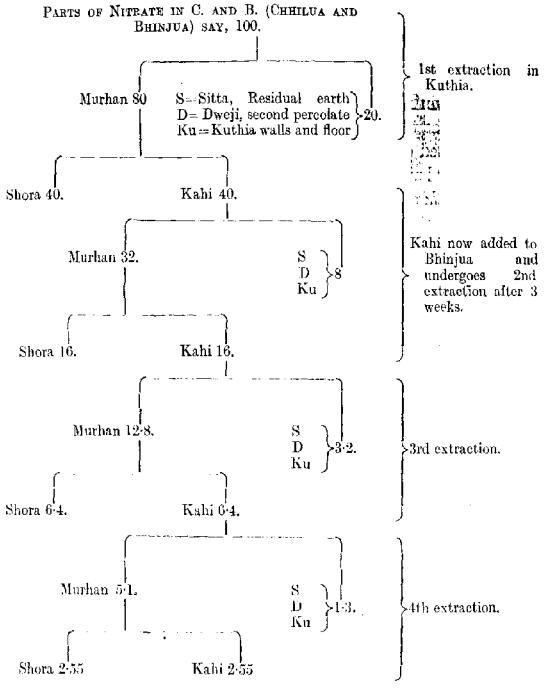
In the ordinary process of the *nuniah* the saltpetre remaining in the mother liquor or *kahi*, amounting to some 40 per cent of that originally put into the *kuthia* as earth, is returned into circulation again by admixture with the residual earth in the preparation of *bhinjua*, so that it is not lost, but contributes a further 80 per cent of its content to the next *murhan* taken from it, half of this amount being removed as *shora* and half going back once more into the factory store as *bhinjua*; thus at each extraction 40 per cent of the *kahi* nitrate of the previous one contributes to the production of *shora*.

From the description of the method of preparing *bhinjua* it will be seen that about three weeks are required for this process, so that this gradual recovery of the nitrate from *kahi* taking place at intervals of about a month would require at least three months to carry out; at the same time transfers of nitrate from the *kahi* itself to the residual earth would be going on, as above described, so that the whole of the nitrate of the original portion of *kahi* under consideration would not be recovered in this way, a considerable percentage of it going into the residual earth and not coming into circulation again until the following year. It will be seen, therefore, that the *nuniah's* process is far from being an efficient or economically sound one, even although he adopts several ingenious methods of preventing the total loss of that portion of his nitrate which he fails to secure directly during the first extraction.

The diagram below will serve to indicate more clearly the circulation of the nitrate as above described. It is necessary here to mention the fact that varying amounts of nitrate are absorbed by the earth forming the walls and floor of the *kuthia*, especially if the latter is a new one; this fact being recognized by the *nuniah*, who breaks up his *kuthia*, generally after two months' service, and uses the earthen walls and floor in the preparation of *bhinjua*.

In the diagram the letters S. D. Ku. signify Sitta, Dweji, and Kuthia the associated figures indicating the amounts of nitrate which are diverted from the main channel of *murhan* into these side ones.

DIAGRAM ILLUSTRATING PARTIAL RECOVERY OF NITRATE FROM *KAHI*.



Shora—Total obtained = 65 of which 25 is recovered from *Kahi* (40) of first extraction remaining 15 being lost as S. D. Ku. (12·5) and unrecovered *Kahi* (2·5).
Chhilua = Scraped earth from villages.
Bhinjua = Prepared earth ("Moistened").
Murhan = 1st Percolate from Kuthia.
Kahi = Mother liquor from which Shora has been taken out.

Starting with a mixture of *chhilua* and *bhinjua* (C. & B.) containing 100 parts of nitrate, about 80 will go into the *murhan* and 20 be diverted or remain in the *sitta*, *dweji* or *kuthia* walls or floor. Of this 80 in the *murhan*, 40 will be got as *shora* and 40 remain as *kahi*. The ultimate fate of this 40 *kahi* fraction is indicated in the diagram and it will be seen that after three times being used for the preparation of *bhinjua* and with subsequent extraction, assuming the

same proportional distribution amongst the resulting fractions, 25 parts out of the original 40 are recovered as *shora*, 15 being carried over into *silta* and unrecovered *kahi*.

The actual amounts and with them percentages of the original nitrate in the earth put into the *kuthia*, recovered as *shora* vary with the richness in nitrate of the soil undergoing extraction, so that such calculations as the above are only rough approximations to the average although based on actual analyses of considerable numbers of samples. On the other hand whatever may be the percentage of nitrate extracted from the *kuthia* by the percolating water which goes to form the *Murhan* or first extract, so long as the concentration of this extract is carried to the usual point habitual with the *nuniah*, no more than about half of its nitrate will be obtained as *shora*, the other half remaining in the mother liquor or *kahi*, and undergoing the slow process of recovery, with attendant losses so far as the current season is concerned, above described. It has already been explained that although more nitrate could be got out of the extract by further concentration by heating, this cannot be done without at the same time producing a separation of salt, forbidden to the *nuniah* by the Salt Department because of the difficulty of supervising an operation carried out on a small scale by such a large number of individuals. It would appear therefore that the industry is hampered by this restriction on account of the inefficiency introduced as above described into the *nuniah's* process, but as a matter of fact the problem is by no means so simple as it appears at first sight. Actual experiments carried out by *nuniahs* under the writer's supervision, in which further concentration of the mother liquor or *kahi* yielded a second crop of saltpetre and also one of salt, showed an actual loss of nitrate of serious amount, probably due, as was suggested to the writer by Mr. W. A. Davis, Indigo Research Chemist, to purely chemical action resulting from the presence of large quantities of salts of magnesium in the mother liquor; Mr. J. N. Mukherji has informed the writer that he has witnessed the escape of oxides of nitrogen as gas bubbles from the refiner's boiling pan, due to decomposition of the saltpetre consequent on overheating and inevitably resulting in serious loss from this cause. It is therefore possible that the *nuniah* in complying under protest with the requirements of the Salt Department and refraining from the concentration of his mother liquor necessary to obtain a second crop of *shora*, actually avoids an immediate loss of nitrate which would be of a much higher order than that consequent upon the protracted alternative method of recovery in general use.

On the other hand the demonstration of this method of securing a second crop of *shora* which the writer was able to obtain from a *nuniah*.

was carried out under conditions which may not have been such as would be selected by him in ordinary practice, and other considerations make it appear probable that given a free hand and no salt restrictions the *nuniah* would be able to recover a higher percentage of the nitrate actually present in his *murhan* than is obtained by his usual process, and would as a consequence be in a position to handle more of the raw materials of his trade in the same time. At present it will be seen that about half of the earth he is extracting has already been through his *kuthia* whereas were it possible to recover more than fifty per cent of the nitrate the *murhan* contains in one operation, a corresponding diminution of the *bhinjua* fraction of the *kuthia* earth with an equivalent rise in the *chhilua* portion would be possible. This would mean the power of dealing with more of the latter and so increasing the actual out-turn of saltpetre per individual *nuniah* engaged in the industry. Any attempt to improve the condition of the industry with a view to increasing the output of saltpetre, must take this point into consideration.

So far as the temptation to separate salt is concerned, it may be pointed out that the salt actually obtained by concentration of the mother liquor contains only about fifty per cent sodium chloride, the remaining half being a mixture of chlorides and sulphates of potassium, magnesium, and calcium which detract so much from its value as a condiment as to make it practically unmarketable for this purpose and only fit for cattle. This is also the case with the salt produced by the refiner, which commands such a low price on the market, as to make it a very general practice to destroy it rather than take the very small profit (about 4 annas per maund) represented by the difference between its sale price and the license fee. It is to be considered whether the value of this impure salt as a constituent of cattle food or possibly as a manure for special crops, such as the coconut palm, might not make it worth while to devise a scheme for denaturing it so as to avoid excise complications.

The average *nuniah* professes to dispose of his *kahi* as above described in the preparation of *bhinjua*, but calculation based on observation of the amounts of *bhinjua* prepared and of *kahi* utilized in doing so, make it clear that he must either use some of the latter in some other way or throw it away altogether; this latter alternative is altogether too foreign to the instincts of this class to be at all a probable one, and the conclusion that a certain amount of *kahi* is concentrated further in order to obtain a second crop of *shora*, and incidentally one of salt, seems inevitable if any reliance is to be placed upon the statements of *nuniahs* as to their methods of preparing *bhinjua*, which agree so far as

the writer's experience goes, not only with one another but with the practice actually adopted in cases where it was possible to observe them accurately and measure the actual quantities of materials utilized.

The following facts were observed :—

The outfit of a *nuniah* comprises two *kuthias* or filter beds to each *chulha* or fireplace with boiling pan, so that the combined extracts, *murhan*, from these two filters are concentrated on one pan.

Each *kuthia* at one operation takes 8 maunds (640 lb.) of earth composed of equal parts, or thereabouts, of imported earth *chhilua*, and the prepared earth *bhinjua*. The *murhan* boiled down in each pan therefore comes from 8 maunds of *bhinjua* divided between two *kuthias*, and this *murhan* after concentration and crystallization of *shora* is reduced to about one *ghaila* (=10 litres) in volume of *kahi* or mother liquor. This amount of *kahi* is produced each day from the working of the two *kuthias*. Now in the preparation of *bhinjua* the usual amount of *kahi* used is two *ghailas* (=20 litres) to 32 maunds (2,560 lb.) of earth, and as the two *kuthias* require 8 maunds of *bhinjua* between them each day, this necessitates its preparation at the rate of 32 maunds consuming 2 *ghailas* of *kahi* every 4 days, that is half a *ghaila* per day. If more than two *ghailas* of *kahi* are added to 32 maunds of *bhinjua*, the salt concentration is said by the *nuniah* to prevent formation of nitrate in the soil, whereas alternatively, if he prepared twice as much *bhinjua* not only would he find this difficult to do in the time, but his supply of *sitta*, or residual earth, would run short, as also would that of the *chhilua* required to mix with it. Apparently therefore the *nuniah* produces twice as much *kahi* as he is able to use for preparing *bhinjua*, his only ostensible method of recovering the nitrate it contains. An alternative method of recovering the nitrate left in the *kahi* is sometimes adopted, but apparently only very occasionally ; the nitrates adhering to the boiling pan after concentration of the *murhan* are removed by washing with a mixture of *dweji* and *kahi*, and the washings are poured on to a heap of ashes ; this is done at irregular intervals, until an amount of treated ash sufficient to fill a *kuthia* has been accumulated, when the whole heap is packed into a *kuthia* and extracted with water from which *shora* of some 80 per cent purity is said to be got. The writer has had no opportunity of actually observing this operation, which appears to be only infrequently used and he feels a considerable amount of doubt as to the alleged efficiency of a method which, if it were capable of producing *shora* of 80% purity, would probably be more universally adopted.

PLATE IV

THE IMPLEMENTS OF THE TRADE.

The conclusion, therefore, appears inevitable that a considerable quantity of *shora* is obtained by a second concentration, with its attendant disadvantages of loss of total nitrate and necessity for concealment of the production of salt incidental to the process.

The salt obtained is of no particular value to the *nuniah*, not only on account of the difficulties attending its sale but mainly because of its very low quality which unfits it for human consumption. The cultivator who wants salt for his cattle goes to the *nuniah* for it, and in exchange allows the latter to scrape *chhilua* off the walls of his house or from the soil surrounding his cattle shed, but no money transaction appears to be associated with this illicit production, and in point of fact the *nuniah* probably has to destroy or bury a considerable proportion of the salt he produces.

It will be seen from consideration of the quantities above given that something like 25 per cent of the total nitrate passing through the *nuniah's* factory must either be recovered by an illicit process or lost altogether; furthermore, assuming that this illicit process forms part of the *nuniah's* normal routine, it appears that about 40 per cent of this fraction is liable to be lost through the inefficiency of the process; whether this loss could be avoided if the difficulties of operating *sub rosa* were removed, would form an interesting chemical problem, very like the one so admirably investigated by the authors of the Bulletin already referred to (*loc. cit*) and probably capable of a similar successful solution. The *nuniah* himself says that he could produce a higher yield of better quality saltpetre by concentrating his *murhan* further during the first boiling; this of course would involve the separation of salt and is consequently prohibited, but this alternative method along with the rest of the process, requires careful chemical investigation to determine whether, supposing excise restrictions were relaxed or modified, the *nuniah* himself could produce a higher yield of nitrate from the earth which he collects, by some simple variation in his process.

It may be pointed out that the use of the artificial nitre-bed method above referred to as having been tried at Pusa includes an advantage in respect of the fact that the amount of sodium chloride present in the extract is so low as to be practically negligible; thus any factory working this process could be exempted from the ordinary restrictions of the Salt Department.

It is to be considered whether it would be to the advantage of the industry if refining were carried out by the *nuniah* himself; the *nuniah* is quite capable of producing refined saltpetre with no other implements or apparatus than those he already possesses, as has been demonstrated more than once to the writer, but there are two bars to this at present,

one the concurrent salt separation, and the other the purely economic one of the *nuniah's* poverty. This class of worker is too poor to be able to store refined saltpetre or to pay the license fee for so doing, both of which he is required to do by the Salt Department.

The *nuniah's* tradition is that in the old days, before the Dutch instituted the saltpetre refineries, which were the antecedents of most of the present Indigo factories, the *nuniah* himself was a monied man producing and selling refined saltpetre; then came the employment of servants to do the work, a natural stage in other Indian industries also and the gradual passing into their hands of the knowledge of the craft, coupled with the transference of the original rights in the business to other proprietors, generally money-lenders, knowing little or nothing of the actual methods employed, but ready to sell their interest to traders. It seems probable that such traders, buying the *nuniah's* refined saltpetre would find it varying largely in quality and difficult to market for this reason; the institution of refineries producing a more standardized article of commerce, would be the natural outcome of this state of affairs and a recognition at the same time of the great variation in quality which probably characterized the *nuniah's* product and which, even more than a hundred years since, when the standards of commerce were relatively elastic, made a second refining operation necessary. It is interesting to note that the demand for standardized products created by modern competitive trade methods, is in much the same way affecting another industry now carried on on the sites of the old saltpetre refineries.

The conclusion seems to be that the *nuniah* is no more likely now than in former days, to produce saltpetre of such even quality as to fulfil the demands of the trade, and that consequently refineries are required for standardization of the product. Even in the case of the demand for crude saltpetre for manurial purposes, which is fairly large especially in Ceylon, standardization of some kind is necessary, and without it trade in this commodity is bound to be hampered by the necessity of buying in small lots characteristic of marketing products of very varying composition. Nevertheless the necessity of refineries by no means implies an equal one for the relations now existing as between the *nuniah* and the refiner, which in many cases include the intervention of a middleman who inevitably absorbs profits from both, to the great detriment of the industry. A refinery offering a fair price for fairly pure *shora* and using the improved method devised by Messrs. Leather and Mukerji, would almost certainly obtain constant supplies of crude material and sell the refined product at a good profit. If at the same time the process of the *nuniah* could be improved so as to

secure a higher percentage of recovery of nitrate from his earths without the necessity for evading the restrictions of the Salt Department, this would ensure not only a larger output per *muniah* employed in this trade but an increase in their number.

Formation of nitrates in residual earth. All *muniahs* and refiners believe that nitrate "grows" in their residual earths, and the whole method of the *muniah*, involving the preparation of *bhinjua* and the storage of the residual earth or *sitta*, is based upon a recognition of this belief, which is in fact supported by the bacteriological investigations carried out in this laboratory during the past year.

The conditions necessary for nitrification have been described as occurring in the saltpetre districts in a highly favourable degree, and as the "growth" of saltpetre in a soil merely means the conversion of nitrogen from the condition of forming part of an organic compound such as the urea of urine to that of the mineral potassium nitrate by this natural bacterial process, any nitrogenous organic matter contained in the residual earth will eventually yield nitrate if the latter is appropriately treated. Analyses of the imported earth (*chhilua*) show that it contains, besides ready formed nitrates, considerable quantities of organic nitrogen, so that the *muniah's* labours in collecting this earth bring into his factory both actual and potential saltpetre nitrogen, the first of which is taken out by its passage through the *kuthia* and the second put on one side with the *sitta* or residual earth, to be nitrified slowly during the several months period of its storage, the final operation of preparing *bhinjua* considerably accelerating this process.

The actual amounts of organic nitrogen brought in and undergoing nitrification subsequently, naturally vary greatly in different samples, but the following figures taken from actual analyses will suffice to show the relative importance of the action :—

Nitrification in residual earth (Sitta).

	KNO_3 per cent.
Nitrate in *sitta* from Kuthia	0·0431
" " three months old	0·0604
" " twelve months old	0·3220
" " two years old	0·0560

Nitrification in Bhinjua during preparation.

	KNO_3 per cent.
Nitrate after 2 weeks preparation	1·390
" " 3 " "	1·979
" " 4 " "	2·115

This sample of *bhinjua* was prepared from *sitta* containing a percentage of organic nitrogen rather lower than the average of most of

the samples examined, nevertheless the rapid increase in the amount of nitrate nitrogen illustrates the importance of this operation as adding to the resources of the *nuniah*.

On 32 maunds of *bhinjua*, the amount usually prepared at one time this would represent an increase (between 2 weeks and 4 weeks) of nitrate from an initial 33 lb. to 61 lb. pot. nitrate, corresponding to the above analytically determined rate which would add appreciably to the amount of *shora* recovered. It should be pointed out, however, that the apparently rapid increase in the amount of nitrate between the stages of twelve months old *sitta* (0·322 %) and two weeks old *bhinjua* (1·390 %) is partly due to that added as *kahi* in the preparation of this earth; this would amount to about half the quantity found in the two weeks old *bhinjua*. A similar increase in nitrate goes on in the residual earth of the refinery, derived, as has been pointed out above, from the *gad* or sediment of the *nuniah's* boiling pan. Messrs. Leather and Mukerji find some difficulty in accounting for the increase of nitrate in the factory earth, owing to the fact that the *nuniah* does not add organic matter thereto and suggest fixation of atmospheric nitrogen as a possible explanation, but this supposition is not necessary to account for the increase. An average sample of *chhilua* containing about 5·4 % potassium nitrate also contained 0·26% of organic nitrogen, which if completely nitrified would yield potassium nitrate corresponding to a further 1·8% thus adding 25% of the total yield from this soil. Experiment has shown that nitrogen-fixing organisms are generally present in these soils, but not to any abnormal extent, nor are the conditions obtaining in them so favourable to this action as to make it probable that any appreciable increase is due thereto.

The question naturally arises, how did the *nuniah* discover that nitrate is formed in his residual earth, and further, how did he devise the *bhinjua* method of increasing this formation. The first discovery was no doubt due to the natural phenomenon of rise to the surface and formation of efflorescences thereon which gave rise to the industry itself, but the preparation of *bhinjua* is of too complex a character to be explained entirely by the yield of nitrate therefrom. The addition of ashes, although no doubt actually serving to convert nitrates of lime and magnesia into nitrate of potash, apparently fulfils other important functions well known to the *nuniah;* the first one is to regulate the distribution of the water added (as *dweji* and *kahi*) and prevent the occurrence of puddling, highly inimical to nitrification; the second, as described by the *nuniah*, is to secure better crystallization, *i.e.*, the formation of larger crystals, of the *shora*. Experiments with *bhinjua* prepared by the *nuniah* on the ordinary scale showed no increase of

nitrification when ashes were added, over a parallel sample without such addition. No doubt there are many ways known to the chemist by which the presence of salts in solution such as would be derived from the added ashes, would minimize the interference with filtration and crystallization due to colloids present and the magnesium salts also which interfere with good crystal formation, but the efficiency of the method is a triumph of pure empiricism so far as the *nuniah* is concerned, this process as well as the rest of his methods being mixed up with such curious superstitions as appear to be inevitably associated with crafts connected with the recovery of minerals from the earth. The *nuniah* believes for instance that a mixture of samples of *chhilua* brought from widely separated areas of collection will yield more saltpetre than the same quantity from any one of them however rich it may be; he also believes in the necessity for mixing *bhinjua* with his *chhilua*, although the former may not contain so much nitrate as the latter, and this belief no doubt is founded upon the observed results connected with the action of the ashes added to the *bhinjua* during preparation. The "growth" of nitrate in his residual earth and its occurrence in village soils he attributes to a mysterious influence which living things, both men and animals, have upon their immediate surroundings, and this influence he believes can be transferred, as a species of "contagium vivum" by adding an "inoculum" of "live" soil to a previously inert one. This belief is somewhat analogous to that held by miners, who hold that fresh supplies of metalliferous ores are generated in worked-out veins by the action of a slime which they designate as the "mother" of the metal concerned.

SUMMARY.

The general conclusions arrived at from the above study of the facts connected with the production of saltpetre by the *nuniahs* of Bihar may be summarized as follows:—

(1) The present sources of saltpetre are not fully utilized on account of the drawbacks at present associated with the *nuniah's* business and the low price of crude saltpetre.

(2) Artificial nitre-beds, on account of the favourable soil and climatic conditions in Bihar, would probably form a useful added source of saltpetre.

(3) The *nuniah's* present methods do not allow of recovery of all the nitrate present in the earths he works with. It is to be determined whether a better method of extraction

could be devised capable of being carried out by the *nuniah* and whether the efficiency of this method would necessarily depend upon some relaxation or revision of the restrictions at present imposed by the Salt Department.

(4) The present conditions of trade in this commodity require examination to determine whether a greater demand for Indian saltpetre would result from organized efforts to improve them, such as the elimination of the middleman and the standardization of the product itself.

PUSA,
August, 1916.

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